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(54) **ACOUSTIC FEEDBACK EVENT MONITORING SYSTEM FOR HEARING ASSISTANCE DEVICES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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See application file for complete search history.

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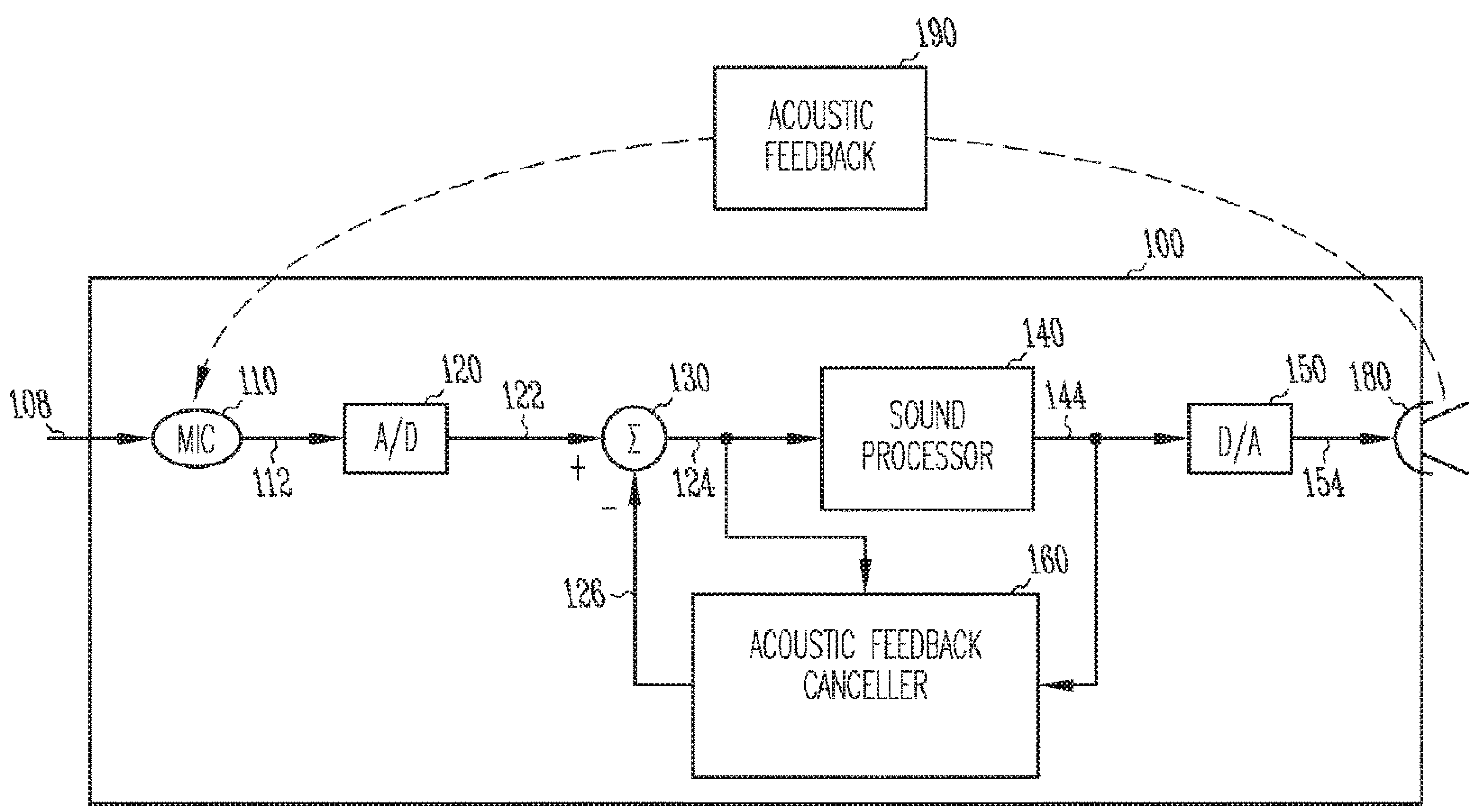
(57) **ABSTRACT**

The present disclosure relates to tracking of acoustic feedback events of a hearing assistance device, such as a hearing aid. Information about the acoustic feedback events is stored for analysis. Such information is useful for programming acoustic feedback cancellers and other parameters of a hearing assistance device.

20 Claims, 3 Drawing Sheets



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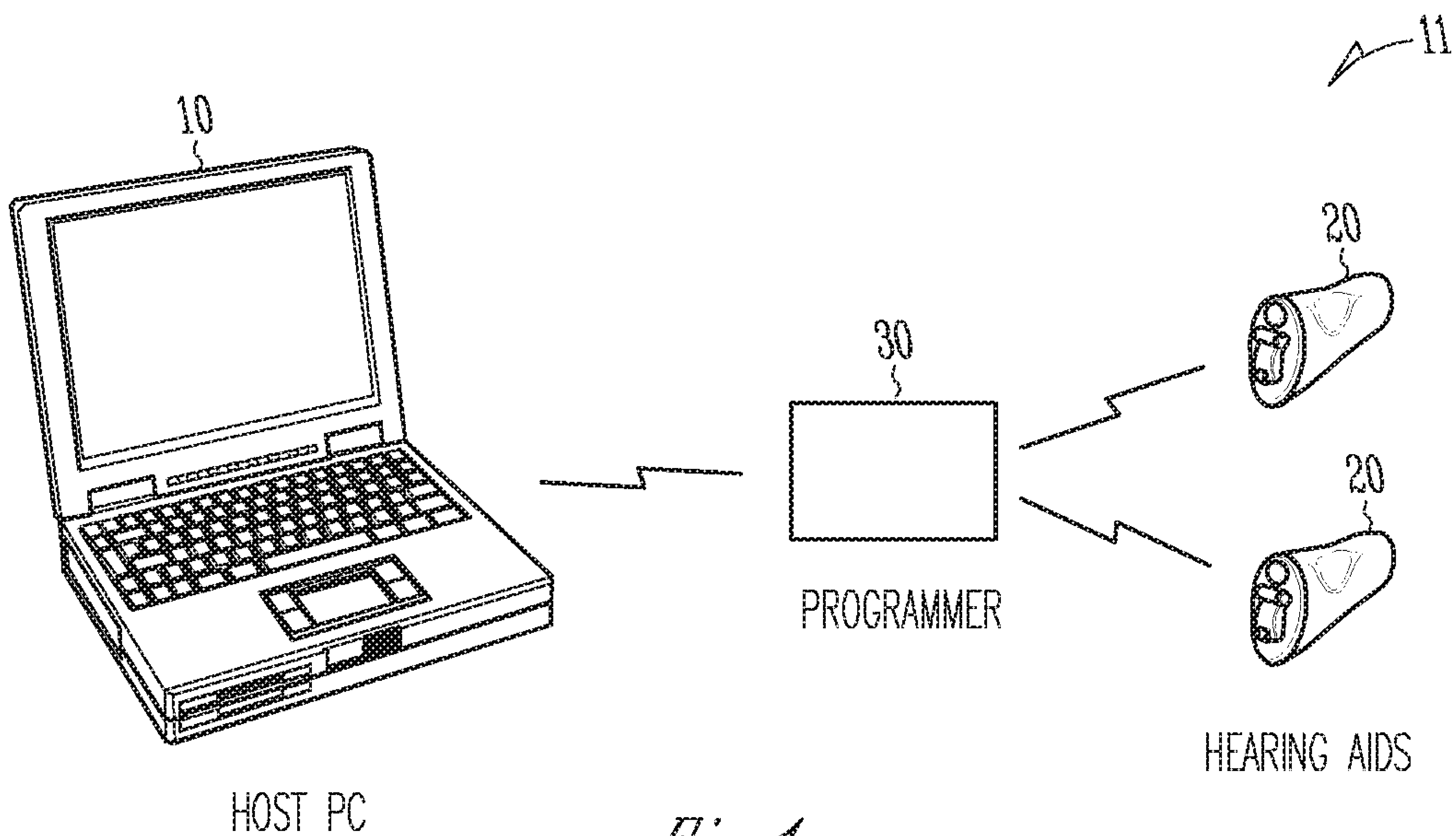

Fig. 1

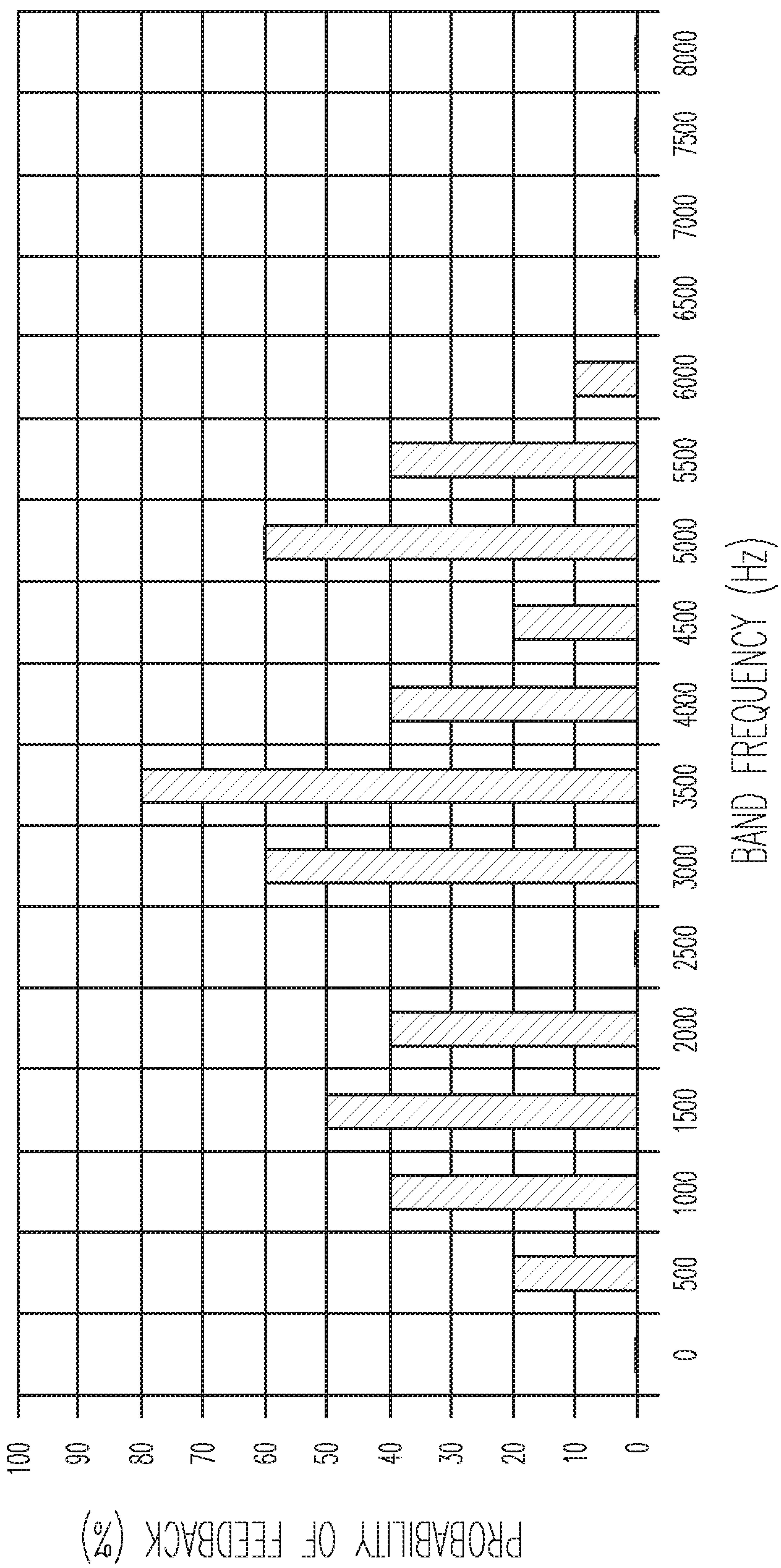
PROBABILITY OF FEEDBACK (%)
0
10
20
30
40
50
60
70
80
90
100
BAND FREQUENCY (Hz)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000

Fig.2

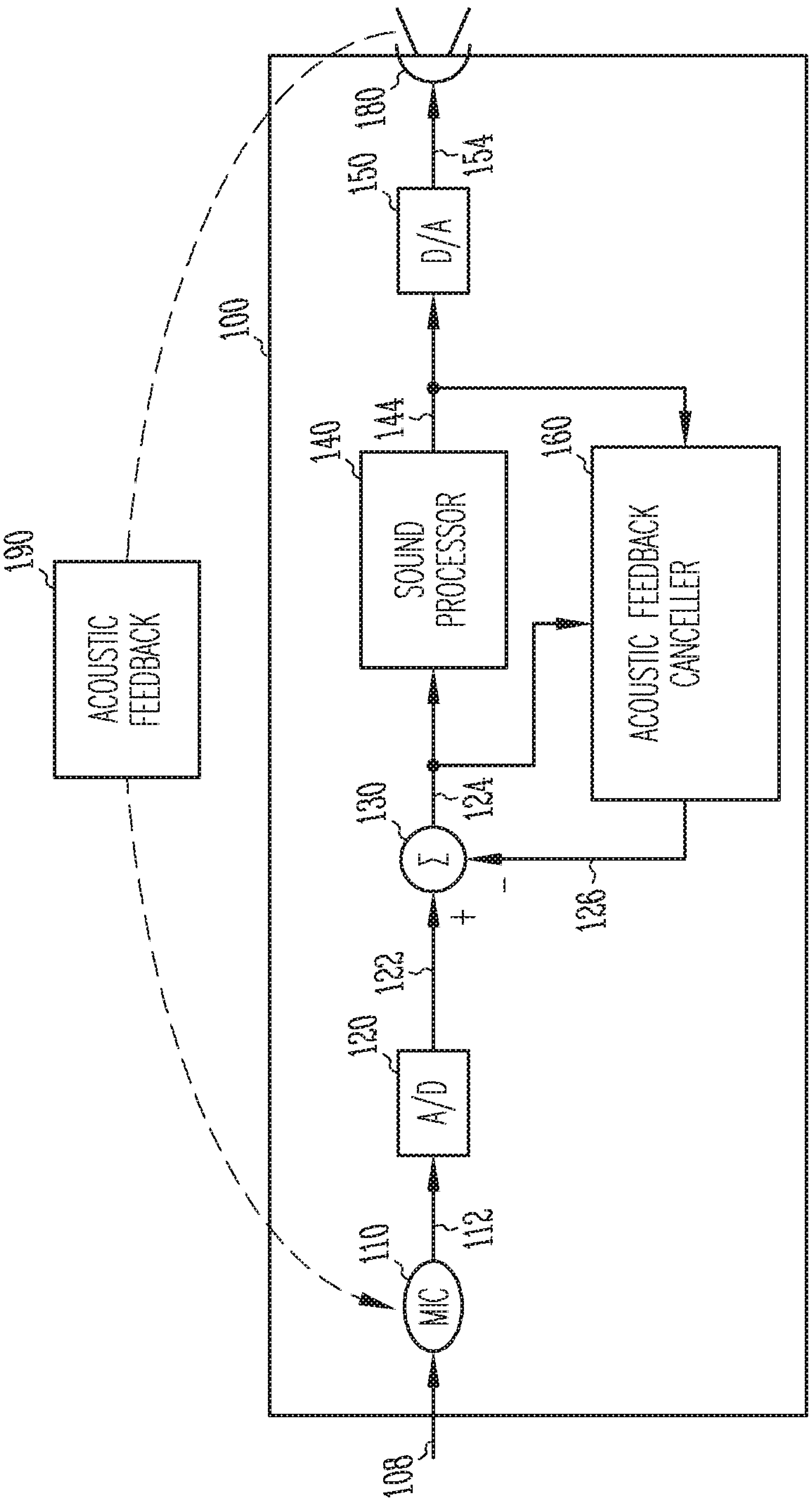
190
ACOUSTIC FEEDBACK
100
108
110
MIC
112
120
A/D
122
+
130
Σ
−
126
124
140
SOUND PROCESSOR
144
160
ACOUSTIC FEEDBACK CANCELLER
150
D/A
154
180

Fig. 3

ACOUSTIC FEEDBACK EVENT MONITORING SYSTEM FOR HEARING ASSISTANCE DEVICES

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 12/644,932, filed Dec. 22, 2009, now issued as U.S. Pat. No. 9,729,976, which is incorporated by reference herein in its entirety.

RELATED APPLICATION

This application is related to U.S. patent application Ser. No. 11/276,795, filed Mar. 14, 2006, which is also published as U.S. Patent Application Publication No. 2007/0217620 on Sep. 20, 2007, and titled: "SYSTEM FOR EVALUATING HEARING ASSISTANCE DEVICE SETTINGS USING DETECTED SOUND ENVIRONMENT," which documents are all incorporated by reference in their entirety.

FIELD OF THE INVENTION

The present subject matter relates generally to hearing assistance devices, including, but not limited to hearing aids, and in particular to an acoustic feedback event monitoring system for hearing assistance devices.

BACKGROUND

Modern hearing assistance devices typically include digital electronics to enhance the wearer's experience. In the specific case of hearing aids, current designs employ digital signal processors rich in features. Modern hearing aids include acoustic feedback cancellation functions. Acoustic feedback cancellation provides very rapid correction of the response of the hearing aid to avoid acoustic feedback. It is difficult to adjust settings of an acoustic feedback cancellation system because they are not limited to electronic or software aspects. These settings are also a function of the acoustics of the environment experienced by the wearer of the device and the fit of the device for the particular wearer.

With the increase of the use of open fit configuration hearing assistance devices, such as receiver-in-the-canal (RIC) or receiver-in-the-ear (RITE) hearing aids, there is an increasing need for higher gain solutions and thus more attention is placed squarely on the acoustic feedback cancellation function. It is important to obtain as much information about the acoustic feedback experienced by the wearer and the operation of the acoustic feedback canceller to provide the desired higher gains with reduced feedback problems for hearing aid wearers.

Audiologists have struggled with lack of information regarding feedback problems that the wearer experienced in use of the hearing aids. Information such as the band at which feedback happens or the severity of the problem is not easy to get from the hearing aid wearer. This may lead to unnecessary reduction in gain at places where feedback is not of a problem resulting in reduced audibility and an unhappy customer.

The options available currently in the market for audiologists are limited. Information that is currently available for an audiologist is typically limited to patient's feedback condition while in the audiologist office. This information is limited and time consuming to acquire.

What is needed in the art is a system for improved monitoring of acoustic feedback events for hearing assistance devices. The system should provide robust and easily accessible information to allow for improved adjustment of hearing assistance devices.

SUMMARY

Disclosed herein, among other things, are methods and apparatus for hearing assistance devices, including, but not limited to hearing aids, and in particular to an acoustic feedback event monitoring system for hearing assistance devices.

The present disclosure relates to tracking of acoustic feedback events of a hearing assistance device, such as a hearing aid. Information about the acoustic feedback events is stored for analysis. Such information is useful for programming acoustic feedback cancellers and other parameters of a hearing assistance device.

In various embodiments, the present subject matter provides apparatus for storing information relating to acoustic feedback events of a hearing assistance device, including a microphone; a receiver; a digital signal processor adapted to process an input signal and generate an output signal, the digital signal processor adapted to perform a process to reduce acoustic feedback between the receiver and the microphone, the digital signal processor further adapted to store information relating to the acoustic feedback events over an extended period of use of the hearing assistance device, wherein the information is accessible for analysis to determine aspects of the acoustic feedback experienced by the hearing assistance device over the extended period of use, the extended period of use including different acoustic environments experienced by a wearer of the hearing assistance device during use of the hearing assistance device. Various embodiments provide multiband or subband approaches. Various embodiments provide storage on the hearing assistance device and remote from the hearing assistance device. Various embodiments store information including one or more of a total number of occurrences of a feedback event, a severity of a feedback event, or a number of feedback events per unit time. Various embodiments include but are not limited to different types of hearing aids, such as behind-the-ear, in-the-ear, and receiver-in-the-canal hearing aids. In various embodiments, wireless communications are provided to perform storage and/or transfer of the information.

Various embodiments provide methods for monitoring performance of a hearing assistance device having an acoustic feedback canceller, the methods including tracking information about a plurality of acoustic feedback events over an extended time interval of use of the hearing assistance device to monitor performance of the acoustic feedback canceller in different acoustic environments experienced by a wearer of the hearing assistance device; and storing the information for analysis. Various embodiments provide multiband or subband approaches. Various embodiments provide storage on the hearing assistance device and remote from the hearing assistance device. Various embodiments store information including one or more of a total number of occurrences of a feedback event, a severity of a feedback event, or a number of feedback events per unit time. Various embodiments include but are not limited to different types of hearing aids, such as behind-the-ear, in-the-ear, and receiver-in-the-canal hearing aids. In various embodiments, wireless communications are provided to perform storage and/or transfer of the information.

This Summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. The scope of the present invention is defined by the appended claims and their legal equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing hearing assistance devices and programming equipment, according to one embodiment of the present subject matter.

FIG. **2** demonstrates one type of output possible with the present system, according to one embodiment of the present subject matter.

FIG. **3** shows a functional block diagram of a hearing assistance system according to one embodiment of the present invention and a representation of an acoustic feedback path.

DETAILED DESCRIPTION

The following detailed description of the present subject matter refers to subject matter in the accompanying drawings which show, by way of illustration, specific aspects and embodiments in which the present subject matter may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the present subject matter. References to "an", "one", or "various" embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment. The following detailed description is demonstrative and not to be taken in a limiting sense. The scope of the present subject matter is defined by the appended claims, along with the full scope of legal equivalents to which such claims are entitled.

The present subject matter relates generally to hearing assistance devices, including, but not limited to hearing aids, and in particular to an acoustic feedback event monitoring system for hearing assistance devices.

FIG. **1** is a block diagram of a system **11** showing a pair of hearing assistance devices and programming equipment, according to one embodiment of the present subject matter. FIG. **1** shows a host computer **10** in communication with the hearing assistance devices **20**. In one application, the hearing assistance devices **20** are hearing aids. Other hearing assistance devices and types of hearing aids are possible without departing from the scope of the present subject matter. In various embodiments a programmer **30** is used to communicate with the hearing assistance devices **20**; however, it is understood that the programmer functions may be embodied in the host computer **10** and/or in the hearing assistance devices **20** (e.g., hearing aids), in various embodiments. Programmer **30** thus functions to at least facilitate communications between the host computer **10** and the hearing assistance devices **20** (e.g., hearing aids), and may contain additional functionality and programming in various embodiments.

The present subject matter provides a means for tracking acoustic feedback events over an extended period of time. The tracking algorithm executes on each hearing aid to be monitored. In various embodiments, the tracking algorithm is performed by the digital signal processor to save acoustic feedback events for analysis. In various embodiments, it is possible that the tracking algorithm can operate at least in part on another device, including, but not limited to, the host computer **10**, the programmer **30**, another hearing aid **20**, or on combinations of the foregoing. It is possible that the tracking algorithm can be executed on another device provided it accesses or obtains information about the feedback event experienced and/or operation of the feedback canceller as it operates on the hearing assistance device.

A good feedback detector in a multiband device can detect accurately the occurrence of feedback in a particular band. A hearing aid that has stored these feedback events is a good source of information for audiologists during follow up visits from hearing aid users. It is understood that such follow ups need not be in person and that using remote access technology, the feedback event data can be reviewed and processed remotely. Device parameters can be adjusted remotely as well. Upon reviewing the feedback event information, the audiologist can set the gain in the hearing aid to suit audibility needs while making the most educated guess to avoid potential feedback problems. In various embodiments, this can be based on the wearer's hearing loss and any preliminary calculation of maximum stable gain of the hearing aid. The hearing aid wearer is asked to come back for a follow up visit at a later time, such as one or two weeks. Other times may be used without departing from the scope of the present subject matter. During this time a feedback tracking algorithm can be run on the hearing aid, or aids, to be monitored. In various embodiments, the tracking algorithm is continually run on the hearing aid. In various embodiments, the tracking algorithm is activated during the 1 to 2 week monitoring period, depending on the preference of the audiologist. In various embodiments, the tracking algorithm is activated upon certain programmable events, such as an acoustic environment change, occurrence of multiple acoustic feedback events, or other programmable events. In various embodiments, there are means in the fitting software to disable or reset the feedback tracking algorithm.

In some embodiments, the feedback tracking algorithm constantly monitors information including, but not limited to, the total number of occurrences of feedback, severity of the feedback, and/or a number of feedback occurrences per unit time until the next follow up. If needed to avoid false alarms, the feedback tracking algorithm can be disabled for a few seconds after power up so that feedback due to insertion of hearing aid into ear is not taken into consideration. The data is collected over an interval of time until the follow up session.

When the hearing aid user comes back to the audiologist office (or in the case of a remote visit, when the data is provided to the audiologist), the fitting software will display the information that would help the audiologist to fine tune the prescribed gain to minimize feedback problems. This allows gain to be reduced in bands of high feedback problems and increase gain (if needed) in bands with no feedback problems. Higher the probability of feedback in a band, more gain reduction can be prescribed in that band. This will ensure that the hearing aid performance is maximized to provide increased audibility while reducing risks of feedback in a convenient, straight forward manner.

FIG. **2** demonstrates one type of output possible with the present system, according to one embodiment of the present subject matter. The data representing feedback occurrences at particular frequencies is statistically collected and provided as a histogram in this example. This type of output tells the audiologist the likelihood of feedback as a function of frequency for a relatively large sample space as opposed to a limited amount of information found during a patient visit. There are different ways that the fitting software can display the information on feedback. Thus, the present discussion is demonstrative and not intended to be an exhaustive or exclusive depiction of the system and its operation.

In various embodiments, the feedback tracking algorithm is adapted to run on the digital signal processor of the hearing assistance device. In some embodiments, the data is statistically collected and stored in memory resident in the hearing aid. In various embodiments, the data is transferred to another storage device. Such devices include data storage accessible over the INTERNET or other network, a personal data storage, such as a personal digital assistant, iPod, cellular phone, or other digital storage device. Such transfer may be performed in a wired or wireless approach, or via a recharging step where the data is downloaded. The wireless approaches including, but are not limited to radio frequency transmission or magnetic coupling transmission. In some embodiments, the data is logged for later processing, such as set forth in U.S. patent application Ser. No. 11/276,795 filed Mar. 14, 2006, which is also published as U.S. Patent Application Publication No. 2007/0217620 on Sep. 20, 2007, titled: "SYSTEM FOR EVALUATING HEARING ASSISTANCE DEVICE SETTINGS USING DETECTED SOUND ENVIRONMENT," which documents are all incorporated by reference in their entirety.

FIG. **3** shows a functional block diagram of a hearing assistance system according to one embodiment of the present invention and a representation of an acoustic feedback path. The hearing assistance system **100** includes a microphone **110**, which receives input sound **108** and provides a signal **112** to an analog-to-Docket digital converter **120**. A digital representation **122** of the signal **112** is provided to the summer **130**. The summer **130**, sound processor **140** and acoustic feedback estimator with adaptive bulk delay **160** are configured in a negative feedback configuration to provide a cancellation of the acoustic feedback **190**. In FIG. **3**, the input sound **108** is desired signal and conceptually separate from acoustic feedback **190**. In providing the cancellation, signal **124** represents a form of error signal to assist in producing the acoustic feedback estimate **126** from acoustic feedback estimator with adaptive bulk delay **160**. Sound processor **140** can be implemented to provide a number of signal processing tasks, at least some of which are found in hearing assistance systems. The resulting processed digital output **144** is received by driver **150** and used to drive receiver **180**. In one embodiment, driver **150** is a digital to analog converter and amplifier combination to drive receiver **180**. In one embodiment, driver **150** is a direct drive. In one embodiment, driver **150** is a pulse width modulator. In one embodiment, driver **150** is a pulse density modulator. Receiver **180** also can vary. In one embodiment, receiver **180** is a speaker. In on embodiment, receiver **180** is a transducer. Other drivers and receivers may be used without departing from the scope of the present subject matter.

Digital output **144** is provided to the acoustic feedback estimator with adaptive bulk delay **160** to create the acoustic feedback estimate **126**. Summer **130** subtracts acoustic feedback estimate **126** from digital representation **122** to create error signal **124**.

It is understood that various amplifier stages, filtering stages, and other signal processing stages are combinable with the present teachings without departing from the scope of the present subject matter.

The sound cancellation is necessary since acoustic output from the receiver **180** invariably couples with the microphone **110** through a variety of possible signal paths. Some example acoustic feedback paths may include air paths between the receiver **180** and microphone **110**, sound conduction paths via the enclosure of hearing assistance system **100**, and sound conduction paths within the enclosure of hearing assistance system **100**. Such coupling paths are collectively shown as acoustic feedback **190**.

If properly implemented the feedback system of FIG. **3** will produce an acoustic feedback estimate **126** which is closely modeled after acoustic feedback **190**. Summer **130** will subtract the acoustic feedback estimate **126** from signal **122**, thereby cancelling the effect of acoustic feedback **190** in signal **124**. As the cancellation becomes ideal signal **124** approaches signal **122**, which is a digital representation of input sound **108**. It is noted that signal **124** is called an error signal only because it represents error to the closed loop system (that is when it departs from signal **122** that is error). When working properly, the information on error signal **124** is the desired sound information from input sound **108**. Thus, the "error" nomenclature does not mean that the signal is purely error, but rather that its departure from the desired signal indicates error in the closed loop feedback system.

The acoustic feedback cancellation is performed using the digital signal processor (DSP) in digital embodiments. The DSP can be used to perform the feedback event tracking function of the present subject matter. Multiband or subband implementations can involve acoustic feedback cancellation that is performed on a band-by-band basis. Therefore collection of acoustic feedback events per band is relatively straightforward.

The present subject matter can be used for a variety of hearing assistance devices, including but not limited to, cochlear implant type hearing devices, hearing aids, such as behind-the-ear (BTE), in-the-ear (ITE), in-the-canal (ITC), or completely-in-the-canal (CIC) type hearing aids. It is understood that behind-the-ear type hearing aids may include devices that reside substantially behind the ear or over the ear. Such devices may include hearing aids with receivers associated with the electronics portion of the behind-the-ear device, or hearing aids of the type having receivers in the ear canal of the user. Such devices are also known as receiver-in-the-canal (RIC) or receiver-in-the-ear (RITE) hearing instruments. It is understood that other hearing assistance devices not expressly stated herein may fall within the scope of the present subject matter.

This application is intended to cover adaptations or variations of the present subject matter. It is to be understood that the above description is intended to be illustrative, and not restrictive. The scope of the present subject matter should be determined with reference to the appended claims, along with the full scope of legal equivalents to which such claims are entitled.

What is claimed is:

1. A method, comprising:

monitoring performance of a hearing assistance device having an acoustic feedback canceller, including tracking information using a processor of the hearing assistance device about acoustic feedback events over an interval of use of the hearing assistance device in different acoustic environments experienced by a wearer of the hearing assistance device, wherein the tracking is activated upon occurrence of a programmable event and wherein the processor is configured to measure a magnitude of severity of a feedback event of the acoustic feedback events and to reduce feedback on a band-by-band basis of a plurality of subbands using the measured magnitude and an acoustic feedback estimate; and storing the tracked information remotely from the hearing assistance device, including storing an indication of the magnitude of severity of the feedback event of the acoustic feedback events for one or more subbands of the plurality subbands, and storing a probability of feedback for the one or more subbands.

2. The method of claim **1**, wherein the processor is configured to reduce feedback using the measured magnitude and using subtraction of the acoustic feedback estimate.

3. The method of claim **1**, wherein storing the information remotely includes storing the information in digital storage accessible over the INTERNET or other network.

4. The method of claim **1**, wherein storing the information remotely includes storing the information in a memory of a personal computer.

5. The method of claim **1**, wherein storing the information remotely includes storing the information in a memory of a portable digital storage device.

6. The method of claim **1**, further comprising transferring the tracked information from the hearing assistance device to a remote device before storing the tracked information at the remote device.

7. The method of claim **6**, wherein transferring the tracked information to a remote device includes using the INTERNET.

8. The method of claim **6**, wherein transferring the tracked information to remote device includes using a wireless network.

9. The method of claim **8**, wherein transferring the tracked information to a remote device includes using radio frequency transmission.

10. The method of claim **8**, wherein transferring the tracked information to a remote device includes using magnetic coupling transmission.

11. An apparatus for storing information relating to acoustic feedback events of a hearing assistance device, comprising:

a digital signal processor configured to monitor performance of a hearing assistance device having an acoustic feedback canceller, including tracking information from a processor of the hearing assistance device about acoustic feedback events over an interval of use of the hearing assistance device in different acoustic environments experienced by a wearer of the hearing assistance device, wherein the tracking is activated upon occurrence of a programmable event and wherein the processor is configured to measure a magnitude of severity of a feedback event of the acoustic feedback events and to reduce feedback on a band-by-band basis of a plurality of subbands using the measured magnitude and an acoustic feedback estimate; and

a memory configured to store the tracked information remotely from the hearing assistance device, including storing an indication of the magnitude of severity of the feedback event of the acoustic feedback events for one or more subbands of the plurality subbands, and storing a probability of feedback for the one or more subbands,

wherein the information is accessible for analysis to determine aspects of the acoustic feedback experienced by the hearing assistance device over the interval of use.

12. The apparatus of claim **11**, further comprising wireless electronics adapted to perform wireless communication of the information.

13. The apparatus of claim **12**, wherein the wireless electronics are configured to perform radio frequency communication.

14. The apparatus of claim **12**, wherein the wireless electronics are configured to perform magnetic coupling communication.

15. The apparatus of claim **11**, wherein the digital signal processor is adapted to store the information including a total number of occurrences of a feedback event.

16. The apparatus of claim **11**, wherein the digital signal processor is adapted to store the information including statistical information about acoustic feedback events.

17. The apparatus of claim **11**, wherein the digital signal processor is adapted to store the information including a number of feedback events per unit time.

18. The apparatus of claim **11**, wherein the apparatus includes a cellular telephone.

19. The apparatus of claim **11**, wherein the apparatus includes a portable digital storage device.

20. The apparatus of claim **11**, wherein the processor is configured to reduce feedback using the measured magnitude and using subtraction of the acoustic feedback estimate.

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